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Carbon Pricing: International Comparison

Until the outbreak of the coronavirus pandemic, global warming was the most critical challenge that the world is facing. The crucial drivers of climatic change and particularly global warming are increasing greenhouse gas emissions, especially CO_2. As the Global Warming Index published by Oxford University Environmental Change Institute shows, global warming has been primarily induced by human activities since approximately 1885 and this human-induced influence has increased dramatically since 1960. Hence, the rise in temperature is approaching critical levels, with an increase of the global average temperature by 1.1°C compared to the pre-industrial period and by 0.2°C referring to global average temperatures in 2011–2015 (World Meteorological Organization 2019). It is the central aim of the Paris Agreement to keep the global temperature rise this century well below 2°C (see Figure 1). As a result of rising global temperatures, far-reaching and drastic consequences like extreme weather conditions, melting of the Arctic sea ice and a rise in sea levels are globally observable and call for urgent action. In recent years, the societal pressures for effective political action have also increased significantly. Consequently, actions against global warming are becoming increasingly important and are playing a central role in the political agenda of nations and global organizations.

At the EU level, a trading system was introduced by the European Commission in 2005, as the cornerstone of the EU's policy to combat climate change. More specifically, the European Emissions Trading system (ETS) was set up as a carbon market with a cap-and-trade system that is set out to continuously reduce emission allowances. It is one of the largest and longest operating trading systems of the world and serves as a role model for other trading systems (Borghesi, Montini, and Barreca 2016). The EU ETS currently covers 45 percent of European Greenhouse gas emissions (European Commission 2019). However, apart from covering only European emissions, this trading system is criticized for not reducing emissions to a sufficient extent to slow down global warming (Schmitt 2017). Furthermore, on a global level, the Paris Agreement entered into force in 2016 after negotiations between 195 countries. The signatory states commit themselves to implementing effective policies to limit global warming to 2°C and to pursue efforts to limit temperature rise to 1.5°C.[1] Under this agreement, nations must submit national climate action plans containing their measures against climate warming. A crucial part of these actions are carbon pricing approaches using either trading or taxation systems to reduce emissions.

The following article gives a basic overview of carbon pricing combined with current data about carbon emissions and international carbon pricing. It sheds light on the basic concepts of carbon pricing approaches referring to taxation and cap-and-trade schemes. First, a general overview of the mechanisms behind the two different approaches is given. Second, emissions are compared internationally and over time. Moreover, the most important fuel types and sectors for carbon emissions are described. Third, the coverage of emissions by pricing schemes is considered. The main part compares pricing schemes in more detail across countries focusing on the time of introduction and basic characteristics, the coverage of emissions, the price for emitting, and resulting revenue as well as exemptions.

POLICY APPROACHES: TAXATION AND CAP-AND-TRADE SYSTEMS

Greenhouse gas emissions induce negative externalities via global warming. For emitters, to account for these negative externalities in their individual decisions (internalization), policy interventions are required. From an economic perspective, there are two mechanisms for the reduction of greenhouse gas emissions. The first one refers to taxation of emitted greenhouse gases, the second one to a cap-and-trade system of greenhouse gas emission certificates. Both systems implement the internalization by setting a price on emissions but differ in their approaches:

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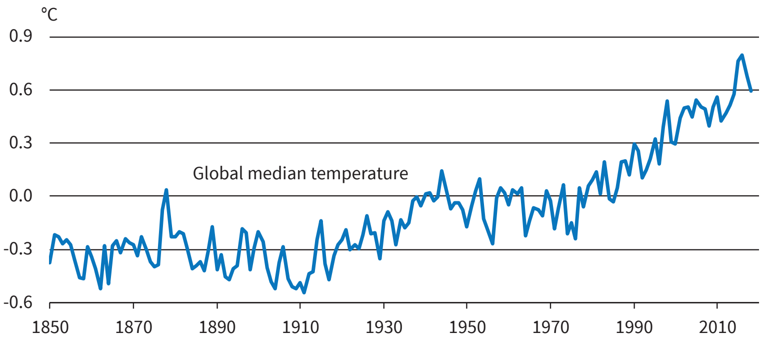
Figure 1
Development of Temperature Anomalities over Time
Relative to 1961–1990 average global temperature



Source: Our World in Data (2019); Hadley Centre. © ifo Institute

[1] Both Celsius goals are measured in respect to pre-industrial temperature levels.

taxation schemes pertain to price regulation approaches, whereas cap-and-trade schemes are categorized as quantity regulation systems. The following section describes the principal mechanisms, highlighting key advantages and disadvantages of both.

The main idea behind taxation schemes is to incentivize emitters to invest in more sustainable technologies. However, it requires that the expenditures needed to reduce emissions by a specific amount (also known as the abatement costs) are lower than the tax burden accumulating from this amount of emissions. As the abatement costs are hard to quantify, setting the right carbon tax is challenging. For example, if the abatement costs are higher than the tax burden, reductions in emissions can be far below the target.

Cap-and-trade systems, on the other hand, consist of a limited number of emission certificates that authorize owners to emit a certain amount of CO_2 and which can be traded within the system. Consequently, emission reduction targets are the principal starting point, as they form the basis for setting the number of certificates. At the beginning, the total number of certificates are delivered by the state via auctions or free allocations. Afterwards, trading is induced by supply and demand, which determines the price of the certificate. Emitters are incentivized to trade their permits, if the price they receive from selling a certificate is higher than the abatement costs. Thus, emitters make a profit by selling the certificate to another emitter whose abatement costs lie above the price of the certificate. As the abatement costs are also uncertain when using a cap-and-trade system, a sharp increase in the price of certificates is possible whenever abatement costs and hence the demand for emission certificates are high. This could lead to a disproportionately higher burden for emitters (Traeger et al. 2019).

CO_2 EMISSIONS WORLDWIDE

Globally, CO_2 emissions have reached their highest level with 36 billion metric tons being emitted in 2017. Emissions have followed an increasing trend for the last 250 years (see Figure 2), with annual growth rates averaging around 3 percent. The sharpest increases occurred with the beginning of industrialization in 1830 with an average rate of 5 percent in the period up until the beginning of World War I. Currently, China and the United States emit the largest quantity of CO_2, as seen in Figure 2[2], followed by India and Russia. China and the US make up 42 percent of global emissions. Including India and Russia, the emissions of top emitters amount to more than half of global emissions (53 percent).

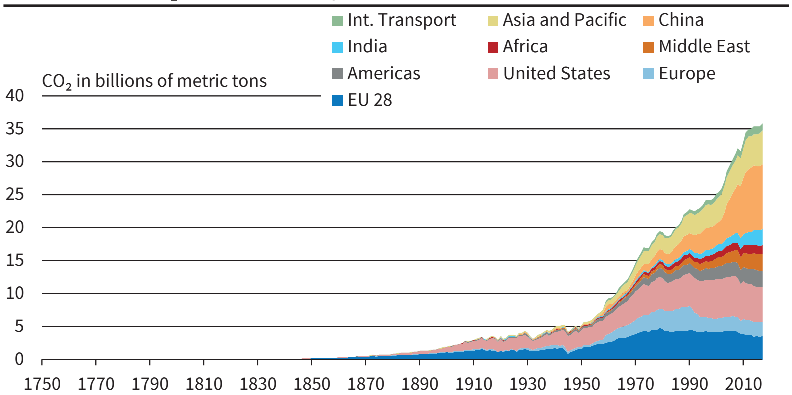
The emissions of China and India in particular have grown in recent years, as opposed to the total emissions of Europe staying relatively constant or even decreasing in the last few decades. In the United States, emissions have remained relatively constant since 1983, with a slight decline in emissions in recent years. While in 1900, the EU28 countries emitted 56 percent of total global emissions, this share dropped to 10 percent in 2017. China and India on the other hand merely emitted 0 percent[3] and 1 percent, respectively, in comparison to total global emissions in 1900. Nowadays, China's contribution to total emissions amounts to 27 percent, while India emits 7 percent of global emissions. The share of emissions produced in the United States and in European countries over time are comparable. In 1990, the US emitted 34 percent of total global emissions, whereas in 2017 the share amounted to 15 percent. The cumulative share of emissions by region further reflects these relative developments (see Figure 3). Here, the crucial finding is that Europe and the United States have contributed most to total global emissions over time.

In addition to total emissions, statistics also capture emissions per capita. Figures 4 and 6 illustrate this difference, with Figure 4 showing emissions by country and Figure 5 showing the per capita emissions. It becomes evident that the largest emitters in absolute terms are in fact not the largest emitters per capita. While China and the United States emit the greatest amount in total, Qatar ranks first in terms of per capita CO_2 emissions with 49 metric tons

[2] International transport (international aviation and shipping), which became relevant in the middle of the 20th century, is excluded as it is not assigned to specific world regions. Hence, the cumulative emissions relative to total world emissions of the last few decades do not add up to 100 percent.

[3] For China, no data is available for 1900, so we use the next available year, which is 1902.

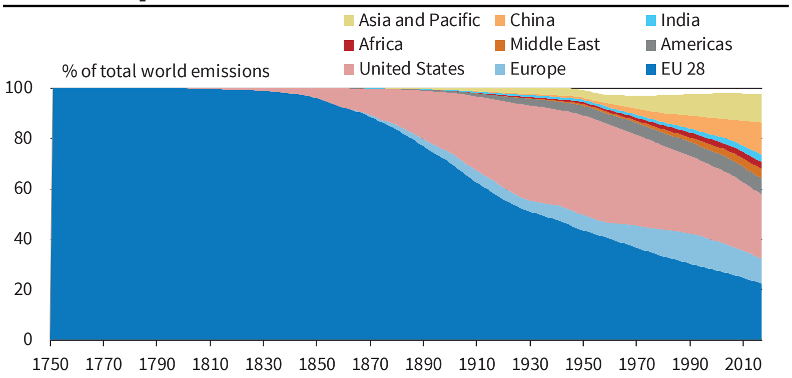
Figure 2
Annual World's CO_2 Emissions by Region, 1751–2017



Source: Our World in Data (2019); Global Carbon Project; Carbon Dioxide Information Analysis Centre (CDIAC). © ifo Institute

Figure 3

Cumulative CO_2 Emissions over Time



Source: Our World in Data (2019); Global Carbon Project; Carbon Dioxide Information Analysis Centre (CDIAC). © ifo Institute

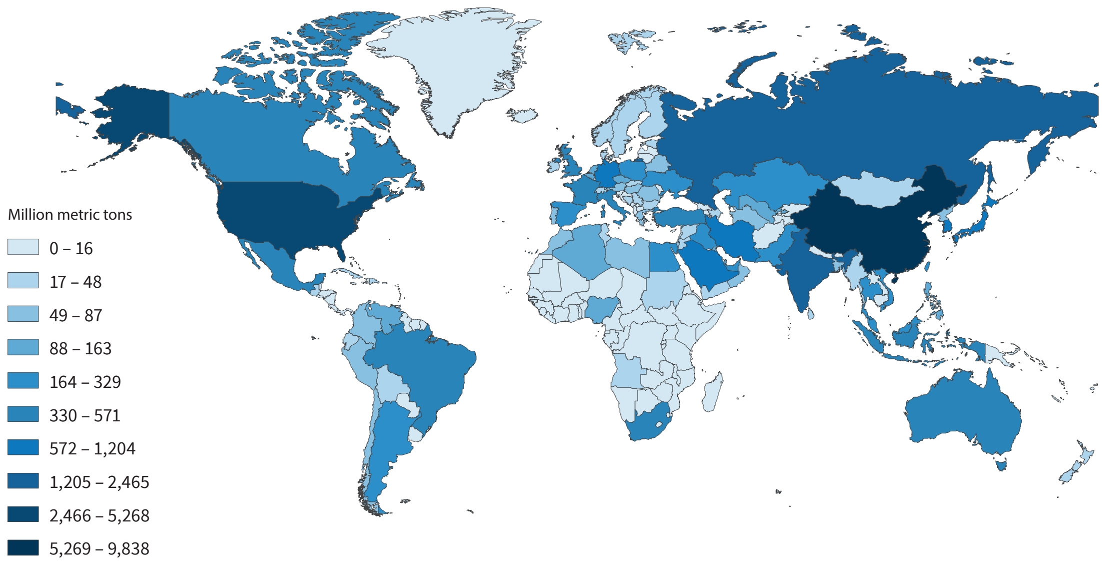
per capita annually, followed by Trinidad and Tobago with 30 metric tons per capita and Kuwait with 25 metric tons per capita. The United States is ranked 9th with 16 metric tons per capita while China is ranked 41st with 7 metric tons of CO_2 per capita.

EMISSIONS BY FUEL TYPE AND SECTOR

Emissions are primarily caused by fossil fuels used in

Figure 4

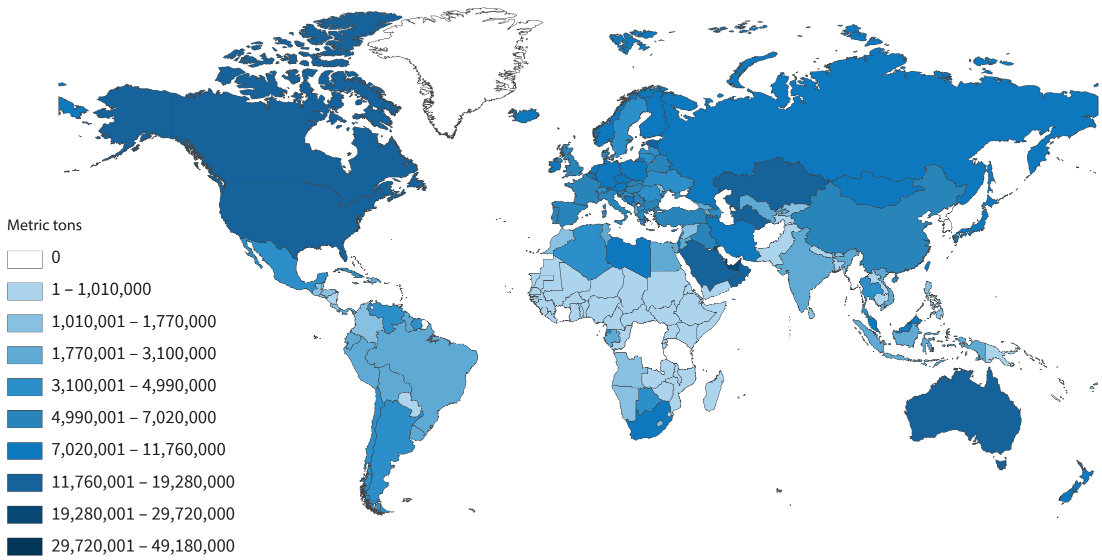
CO_2 Emissions by Country



Source: Our World in Data (2019); Global Carbon Project; Carbon Dioxide Information Analysis Centre (CDIAC). © ifo Institute

Figure 5

CO_2 Emissions per Capita by Country

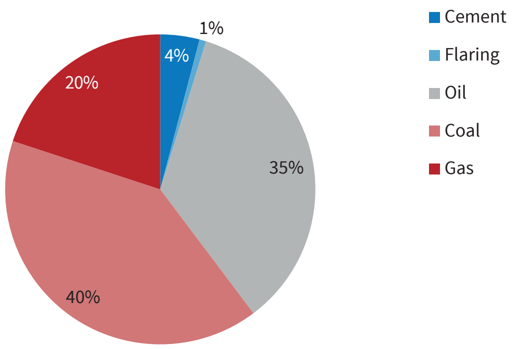


Source: Our World in Data (2019); Global Carbon Project; Carbon Dioxide Information Analysis Centre (CDIAC). © ifo Institute different sectors. Overall in 2017, the world's emissions were associated with five different fuel types (see Figure 6). Coal accounts for the largest share of global emissions (40 percent) followed by oil (35 percent) and gas (20 percent). The remaining 5 percent are associated with the production of cement (4 percent) and flaring (1 percent). The predominant sectors causing emissions are the electricity and heat production sectors, which accounted for 49 percent of total global emissions in 2014 (see Figure 7). Second place was shared by the manufacturing and construction industries and the transportation sector, each accounting for 20 percent of total emissions in 2014. The share of residential buildings and commercial and public services amounts to 9 percent of total global emissions. The remainder of 2 percent is spread across other sectors.

INTERNATIONAL COMPARISON OF CARBON PRICING SCHEMES

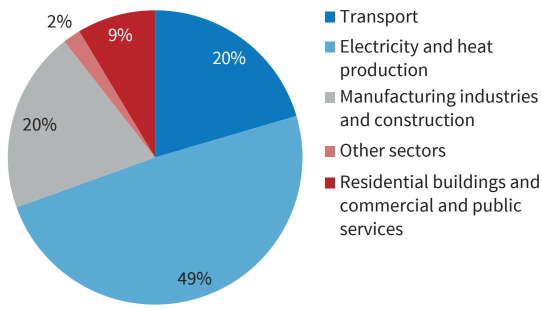
Various carbon pricing schemes have already been introduced at the sub-national, national, and regional level to combat rising greenhouse gas emissions. In addition, several policies are under consideration or already scheduled for implementation. The following section will compare existing international carbon pricing schemes, looking closer at the time of introduction, their coverage, the prices for emissions and resulting revenue, as well as at their effectiveness in reducing emissions.

Figure 6
Emissions by Fuel Type in 2017



Source: Our LZ World in Data (2019); Global Carbon Project (GCP); Carbon Dioxide Information Analysis Center (CDIAC). © ifo Institute

Figure 7
World Emissions[a] by Sector in 2014



[a] CO_2 emissions from transport do not contain emissions for international marine bunkers and international aviation (domestic aviation, domestic navigation, road, rail and pipeline transport).

Source: Our LZ World in Data (2019); Global Carbon Project (GCP); International Energy Agency (IEA) via The World Bank. © ifo Institute

Time of Introduction

In 2019, there were 56 carbon pricing instruments implemented including all carbon tax as well as ETS initiatives on national, regional, and sub-national level. While there were 27 ETS systems, the number of carbon taxation schemes amounted to 29.

Almost one-third of the carbon tax systems were introduced in the 1990s, by Scandinavian countries (Finland in 1990, Norway and Sweden in 1991, and Denmark in 1992) as well as Poland and Slovenia (see Table 1). Most of the carbon taxation schemes were implemented only after 2000. Smaller countries, including Estonia, Latvia, Liechtenstein, Switzerland, Iceland, and Ireland followed by 2010 and Japan followed in 2012 as the first non-European country. More than one-third of the carbon tax policies were introduced in the last five years alone, with national taxation schemes implemented in Canada, Singapore, and South Africa. In Côte d'Ivoire and the Netherlands, taxation systems are scheduled for 2020, and in Senegal taxation schemes are under consideration. Table 1 summarizes the years of introduction for all taxation systems and lists a general description of the specific schemes indicating the differences and variety of structures.

The first trading systems were introduced in 2005, and thus at a much later stage than the taxation systems (see Table 1). While most taxation systems are at the national level (World Bank 2019), the first trading system was introduced at the supranational EU level in 2005. The larger nations of Australia and Canada followed suit in 2016 and 2019, respectively. It is interesting to note that most countries with an ETS system do not implement an additional carbon taxation scheme. However, Switzerland and Canada use both carbon pricing systems (trading and taxation). Moreover, five of the eight countries that already apply a carbon tax system currently have an ETS scheduled or under consideration. For 2020, China has scheduled an emission trading system that is expected to have a large impact on emission coverage, as China is globally one of the largest emitters of greenhouse gases. Many other countries like Chile, Japan, and Turkey are considering trading schemes for CO_2 emission reduction (Table 1).

Emissions Coverage

While introducing carbon pricing policies worldwide is a crucial step toward mitigating climate change, it is important to consider the share of emissions that such policies cover. Overall, both the number of carbon pricing initiatives as well as the share of annual global greenhouse gases covered has increased substantially in the past 20 years. In 2005, the number of implemented policies jumped from 8 to 9 with the introduction of the EU ETS, which led to an increase in covered emissions from 0.25 percent to 3.7 percent globally. A similar jump can be observed in 2012, with the introduction of the carbon tax scheme in Japan, resulting in a total of 24 implemented initiatives and a jump in covered emissions from 4.9 percent to 7 percent.

Looking closer at the emissions coverage, all implemented initiatives covered 14.9 percent of global greenhouse gas emissions in 2019. The EU ETS system accounts for the greatest share of approximately 3.9 percent, followed by Japan’s carbon tax (1.8 percent) and Korea’s ETS

Table 1

Regional and ational Carbon Pricing Schemes Implemented and under Consideration[1]

Country	Year of implementation	Short description
Finland, carbon tax	1990	Component of energy tax, covers life-cycle emissions of fuels for heating and work machines.
Poland, carbon tax	1990	Tax on several emissions, like dust, sewage, and waste.
Norway, carbon tax	1991	Consisting of an excise tax on mineral products and a specific law for petroleum activities on the continental shelf.
Sweden, carbon tax	1991	Component of energy tax for carbon-intensive fuels.
Denmark, carbon tax	1992	Tax on all fossil fuels applying to GHG emissions from mainly the building and transport sectors.
Slovenia, carbon tax	1996	Tax on natural gas and all liquid and solid fossil fuels.
Estonia, carbon tax	2000	Taxes covering all fossil fuels applying to industry and power sectors generating thermal energy.
Latvia, carbon tax	2004	Tax covering fossil fuels from industry and power sectors not covered under the EU ETS.
EU, ETS	2005	Cap-and-trade system with four phases including annual cap reductions and regular updates of exemptions and allowances. It targets CO_2 emissions from the industry, power, and aviation sectors, including industrial processes as well as N_2O from certain chemical sectors and PFC from aluminum production
Liechtenstein, carbon tax	2008	Tax on CO_2 emissions from the industry, power, building, and transport sectors.
Switzerland, carbon tax	2008	Complementary to Swiss ETS on all fossil fuels.
New Zealand, ETS	2008	Trading scheme where government distributes emission certificates to foresters to sell them on the market. Units bought by emitters must be again handed in to the government.[2] It targets GHG emissions from industry, power, waste, transport, and forestry sectors as well as emissions from industrial processes.
Switzerland, ETS	2008	Mandatory cap-and-trade system for large energy-intensive industries (voluntary for medium-sized industries) linked to the EU ETS. It applies to the industry and power sectors as well as industrial processes.
Iceland, carbon tax	2010	Part of Environmental and Resource tax covering liquid and gaseous fossil fuels from all sectors, with exemptions.
Ireland, carbon tax	2010	Tax covering all fossil fuels from all sectors, with exemptions.
Ukraine, carbon tax	2011	Tax covering all fossil fuels from stationary sources.
Japan, carbon tax	2012	Tax covering all fossil fuels for all sectors, with exemptions.
UK, carbon price floor	2013	Tax on CO_2 emissions from power sector, with exemptions.
Kazakhstan, ETS	2013; suspended in 2016–2017; reintroduced 2018	Cap-and-trade system for emissions of large emitters with free allowances based on historical emissions or product-based benchmarks.
France, carbon tax	2014	Part of tariffs on consumption of energy covering all fossil fuels from all sectors, with exemptions.
Mexico, carbon tax	2014	Excise tax on production and services targeting additional CO_2 emission content compared to natural gas.
Spain, carbon tax	2014	Tax on fluorinated greenhouse gases from all sectors, with exemptions.
Portugal, carbon tax	2015	Excise tax on consumption covering all fossil fuels applying to mainly the industry, building, and transport sectors.

[1] This table focuses on national carbon taxes and on regional and national carbon trading schemes. However, there exist sub-national initiatives of carbon taxation schemes as well as sub-national trading initiatives. For example, the regional government of British Columbia in Canada introduced a carbon tax in 2008, hence long before the federal state implemented a federal scheme. Moreover, the province of Alberta in Canada introduced an ETS system in 2007.

[2] https://www.mfe.govt.nz/climate-change/new-zealand-emissions-trading-scheme/about-nz-ets.

Korea, ETS	2015	Cap-and-trade system with benchmark-based allocation of certificates and auctioning, regulations are changed/updated with the start of a new phase of the system. It targets GHG emissions from the industry, power, building, domestic aviation, public, and waste sectors.
Australia, ERF Safeguard Mechanism	2016	Baseline-and-offset system for large emitters incentivizing emissions to be held below specific baselines, which are regularly updated. Above the baseline, Carbon Credit Units must be purchased. The system targets direct emissions including emissions from energy production.[3] It targets emissions from the industry and the power sectors including industrial processes.
Chile, carbon tax	2017	Part of the tax on air emissions from contaminating compounds covering all fossil fuels mainly taxing the power and industry sectors.
Colombia, carbon tax	2017	Tax covering all liquid and gaseous fossil fuels used for combustion targeting all sectors.
Argentina, carbon tax	2018	(Annually increasing) tax covering almost all liquid fuels and coal targeting all sectors, with exemptions.
Canada, federal fuel charge	2019	Legal requirement for all provinces and territories to implement a carbon pricing initiative aligned with federal standards; consists of a regulatory charge on fuels (tax-like component) and a baseline-and-credit ETS for emission-intensive and trade-exposed industrial facilities; applies to GHG emissions from all sectors, with exemptions.
Singapore, carbon tax	2019	Tax targeting GHG emissions from all fossil fuels used by facilities from the industry and the power sector with annual emissions of 25 ktCO_2e or more, exemptions apply to some sectors.
Canada, federal OBPS	2019	Approach for all provinces and territories without carbon pricing scheme or without system aligned with federal standards. It consists of tax-like component on fuels and a baseline-and-credit ETS (OBPS) for emission-intensive and trade-exposed facilities that emit more than 50ktCO_2e annually.
South Africa, carbon tax	2019	Tax on GHG emissions irrespective of the fossil fuel used from the industry, power, building, and transport sectors, with partial exemptions.
	Scheduled and under consideration	
China, ETS	2020	Applies to emissions from the power sector including CHP and power plant from other sectors. Other sectors will be included gradually during the three scheduled phases.
Côte d’Ivoire, carbon tax	2020	Tbd
Netherlands, carbon tax	2020	Carbon floor price for the electricity sector and carbon tax for industry.
Senegal, carbon tax	Tbd	Tbd
Chile, ETS	Tbd	Tbd
Colombia, ETS	Tbd	Tbd
Indonesia, ETS	Tbd	Tbd
Japan, ETS	Tbd	Tbd
Mexico, ETS	Tbd	Tbd
Turkey, ETS	Tbd	Tbd
Ukraine, ETS	Tbd	Tbd
Vietnam, ETS	Tbd	Tbd

[3] https://www.environment.gov.au/climate-change/government/emissions-reduction-fund/publications/factsheet-erf-safeguard-mechanism.

Source: World Bank (2019).

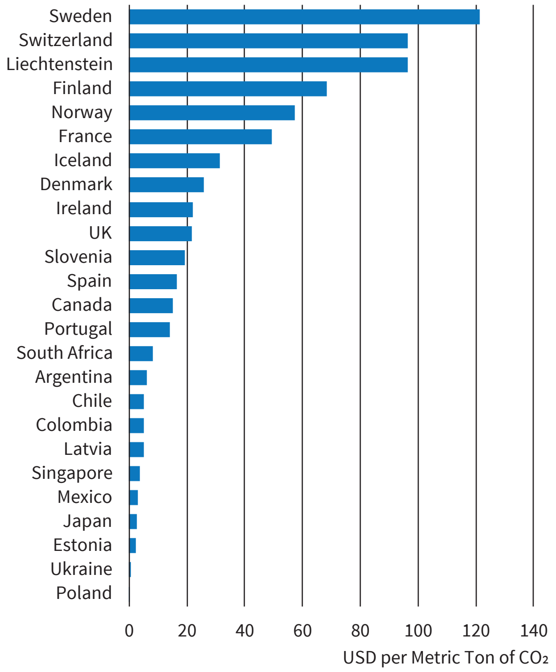
(0.9 percent). Figure 8 displays the share of the total global emission coverage that each individual carbon pricing scheme contributes to. In 2020, a substantial increase in the coverage of emissions is expected due to the introduction of the Chinese ETS system, which is expected to make up more than 25 percent of the future total covered emissions (see Figure 9) and will increase total coverage to 20 percent. The EU ETS had a comparable outreach when it was first introduced in 2005 (World Bank 2019).

Prices and Revenue

The price plays a central role in the taxation systems as it determines the cutoff point at which an emitting firm would decide to adapt an emission-reducing innovation/technology instead of paying the charges for its current emissions. The prices per metric ton of CO_2 (excluding purely fiscal fuel taxes) range from under USD 1 in Poland and Ukraine to a maximum of USD 127 in Sweden (Fig-

Figure 8

Carbon Tax Prices in 2019



Source: World Bank (2019). © ifo Institute

ure 8[4]). The top five countries with the highest prices are Sweden, Liechtenstein, Switzerland, Finland, and Norway.

Figure 9[5] displays the ranking of the prices of trading systems. The European trading system has the highest price, amounting to USD 32 per metric ton of CO_2. With a price of USD 7 per metric ton of CO_2, Switzerland is in last place. In between is the Korean trading system (USD 24 per metric ton of CO_2) and the trading scheme of New Zealand (USD 16 per metric ton of CO_2).

Furthermore, the revenue raised also greatly differs between nations. Figure 10 compares the revenue raised in 2018. Excluding the ETS scheme of the EU with the largest amount of USD 15.948 million, the national carbon pricing schemes range from USD 0.4 million in New Zealand and USD 1 million in Poland to USD 8.1 billion in France (see Figure 10). Sweden raised the second-highest revenue (USD 2.5 billion), closely followed by Japan (USD 2.4 billion). However, both countries' revenue combined is still less than the revenue raised by France. When comparing the price and revenue structure, the rankings diverge. For example, while Japan is one of the five countries with the lowest carbon prices, it is the country with the third-highest revenue. Nonetheless, the Scandinavian countries that exhibit high price levels also accrue high revenue.

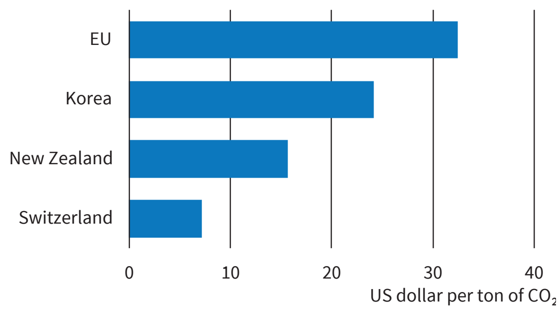
In general, when analyzing the revenue accrued from carbon pricing instruments, the question arises of how these public funds are used. In a cross-country study, Carl and Fedor (2016) find that 27 percent are used for investments in renewable energy and the increase of energy efficiency, 26 percent end up in public expenditures (not particularly linked to specific spending) and the largest part (36 percent) benefit taxpayers through tax cuts or direct discounts. When looking at the revenue from taxation schemes and emission trading systems separately, the authors find that, while revenue from emission trading systems is mostly reinvested into green technologies (70 percent), revenue from taxation schemes is mostly refunded to taxpayers and used for unspecified public expenditures (72 percent).

[4] This overview focuses on the principal price levels for fossil fuels for national carbon pricing schemes. Mexico, Argentina, Denmark, Norway, and Finland differentiate between two price levels for different fuel types. For more information, consult World Bank (2019).

[5] This overview focuses on national and regional ETS schemes. For Australia, Kazakhstan, and Canada, no prices are applicable. For more information, consult World Bank (2019).

Figure 9

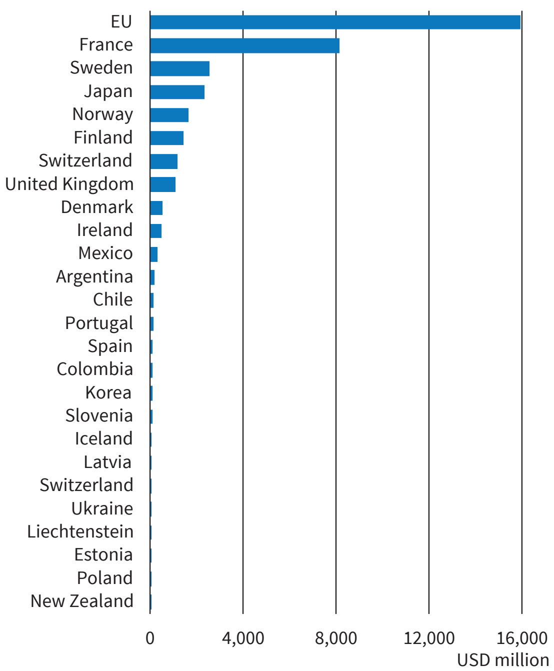
Carbon Trade Prices 2019



Source: World Bank (2019). © ifo Institute

Figure 10

Revenues Raised from Carbon Pricing Schemes in 2018



Source: World Bank (2019). © ifo Institute

Exemptions

Most carbon price schemes have exemptions for specific sectors, fuel types, or energyintensive processes. National governments usually argue that exemptions are necessary in order to protect energy-intensive sectors and the international competitiveness of their national economy (World Bank 2019b). Table 2 gives an overview of (partial) exemptions in national and regional carbon pricing schemes. In general, emitters in European countries already covered by the EU ETS are (partly) exempted from national carbon pricing schemes. The most common exemptions refer to transportation and

Table 2

Exemptions of Carbon Pricing Schemes

Carbon Price Scheme	(Partly) Exemptions from carbon pricing	Others
Argentina carbon tax	☐Industry ☐ Transport ☒ Int. Aviation ☒Int. Shipping ☐Agriculture ☒ Chemical processes ☐ Export of fuels ☐ Power/Heat	
Australia ERF Safeguard Mechanism	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Emitters up to their baseline emission level.
Canada federal fuel charge	☒Industry ☒ Transport ☐ Int. Aviation ☐Int. Shipping ☒Agriculture ☐ Chemical processes ☒ Export of fuels ☐ Power/Heat	
Colombia carbon tax	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Natural gas not used in the petrochemical and refinery sector.
Denmark carbon tax	☐Industry ☐ Transport ☒ Int. Aviation ☒Int. Shipping ☐Agriculture ☐ Chemical processes ☒ Export of fuels ☒ Power/Heat	
EU ETS	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Allowances of up to 100 percent of benchmark level for emission-intensive/trade-intensive sectors at risk of carbon leakage.
Finland carbon tax	☐Industry ☐ Transport ☒ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☒ Power/Heat	Commercial yachting, coal and natural gas in industrial processes.
France carbon tax	☐Industry ☒ Transport ☒ Int. Aviation ☒Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☒ Power/Heat	
Iceland carbon tax	☐Industry ☐ Transport ☒ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	
Ireland carbon tax	☐Industry ☐ Transport ☒ Int. Aviation ☒Int. Shipping ☐Agriculture ☐ Chemical processes ☒ Export of fuels ☒ Power/Heat	
Japan carbon tax	☒Industry ☒ Transport ☐ Int. Aviation ☐Int. Shipping ☒Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Certain uses of fossil fuels in forestry.
Kazakhstan ETS	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Free allowances for all emitters.
Korea ETS	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Allowances of up to 100 percent of benchmark level for emission-intensive/trade-intensive sectors at risk of carbon leakage.
Latvia carbon tax	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Peat.
Liechtenstein	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Emitters with high carbon tax burden and competitiveness risks given that they reduce emissions by a specific amount by 2020, (partially) importers of transport fuels but with obligation to offset emissions.

Mexico carbon tax	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Tax of maximum 3 percent of fuel sales price.
New Zealand ETS	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Allowances of 60-90 percent of benchmark level for emission-intensive/trade-intensive sectors at risk of carbon leakage.
Norway carbon tax	☐Industry ☐ Transport ☒ Int. Aviation ☒Int. Shipping ☐Agriculture ☐ Chemical processes ☒ Export of fuels ☐ Power/Heat	Biofuels in mineral oil.
Poland		Operators with annual tax amount due less than 800 zloty.
Portugal carbon tax	☒Industry ☒ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	
Slovenia carbon tax	☒Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☒ Export of fuels ☒ Power/Heat	
South Africa carbon tax	☐Industry ☒ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Exemptions from 60-95 percent for many sectors.
Spain carbon tax	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Partially the use of fluorinated GHGs in certain sectors.
Sweden carbon tax	☐Industry ☒ Transport ☒ Int. Aviation ☐Int. Shipping ☒Agriculture ☐ Chemical processes ☒ Export of fuels ☒ Power/Heat	Forestry
Switzerland ETS	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Allowances of up to 100 percent of benchmark level for emission-intensive/trade-intensive sectors at risk of carbon leakage.
Switzerland carbon tax	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☒ Power/Heat	Operators with high carbon tax burden and competitiveness risks given that they reduce emissions by a specific amount by 2020, partially importers of transport fuels but with obligation to offset emissions.
UK carbon price floor	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☒ Power/Heat	

Source: World Bank (2019).

heat production. However, these sectors account for a large proportion of emissions (see Figure 7). Hence, against the background of climate targets, criticisms have arisen with respect to such exemptions (see for example Lin and Li 2011; Kemfert et al. 2019).

CONCLUSION AND DISCUSSION

This article describes carbon pricing approaches and their implementation in an international comparison. As shown, nations differ not only as to their carbon emission levels in various dimensions (over time, cumulative, per capita, etc.) but also as to their choice of carbon pricing methods. Most of them can be assigned clearly to one of the approaches. However, pricing schemes combining elements from both concepts are subject to the current scientific discussion. For example, emission trading initiatives with a price floor or ceiling unify trading and taxation elements by setting a maximum and a minimum price for carbon within an emissions trading system.[6]

Other suggestions follow a consumption-based approach, as for example carbon border taxes (also known as carbon tariffs). This approach is designed to address concerns about carbon leakage (firms producing in countries with less strict carbon pricing policies) and the resulting competitive disadvantages for countries due to carbon pricing. Broadly speaking, products from countries with less strict carbon pricing policies are subject to an import tax when they are imported into countries with stricter legislation (Rocchi et al. 2018). And still other

[6] A detailed mixed approach has been developed by the ifo Center for Energy, Climate, and Resources named “Flexcap.” For more detail see for example Traeger et al. (2019).

approaches argue in favor of command and control mechanisms setting binding limits to carbon emissions (Aldy and Stavins 2012).

In sum, research has shown that implementing different instruments of carbon pricing simultaneously can be inefficient (OECD 2011). However, well-designed carbon pricing schemes that combine the advantages of both approaches might be helpful in reducing greenhouse gas emissions effectively as well as efficiently and hence reduce global warming. Therefore, the design of carbon tax schemes as well as their exemptions should be continuously under consideration and open for adjustments in order to prevent global warming from exceeding important temperature limits.

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